

BIOMEDICAL APPLICATIONS OF NASA TECHNOLOGY

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ABSTRACT

Through the active transfer of technology, the National Aeronautics and Space Administration (NASA) Technology Utilization (TU) Program assists private companies, associations, and government agencies to make effective use of NASA's technological resources to improve U.S. economic competitiveness and to provide societal benefit. Aerospace technology from areas such as digital image processing, space medicine and biology, microelectronics, optics and electro-optics, and ultrasonic imaging have found many secondary applications in medicine. Examples of technology spinoffs are briefly discussed to illustrate the benefits realized through adaptation of aerospace technology to solve health care problems. Successful implementation of new technologies increasingly requires the collaboration of industry, universities, and government and the TU Program serves as the liaison to establish such collaborations with NASA. NASA technology is an important resource to support the development of new medical products and techniques that will further advance the quality of health care available in the United States and worldwide.

INTRODUCTION

In the early 1900s, few effective treatments existed for life-threatening diseases because medical care consisted primarily of palliative treatments to mitigate the effects of diseases. Since then, advances in biomedical sciences and technology have produced more effective diagnostic methods and treatments that together have far-reaching effects on medical care and human life expectancy. The pace of technological change in recent decades has been unprecedented, enabling us to reduce infant mortality, to eradicate certain diseases, to replace and repair human organs, and to rehabilitate those with disabilities so that they may live happier and more productive lives.

Through the active transfer of technology, NASA has played an important role in many technological developments that have advanced the quality of medical care in the U.S. and throughout the world. Meeting the aeronautical and space goals of the past three decades has necessitated advancements across a broad spectrum that embraces virtually every scientific and technological discipline. This technology represents an important national resource available for use by public and private sector organizations to develop new or improved products and processes.

To promote the secondary application of aerospace technology in medicine, NASA works with medical device companies, medical universities, major hospitals, and research centers, as well as Federal agencies such as the National Institutes of Health and the Veterans Administration. These collaborations are supported by the NASA (TU) Program whose mandate is to promote the widest practical and appropriate dissemination of the results of NASA's R&D activities. The TU program encourages and facilitates the access and utilization of NASA-developed technology by public and private researchers, developers, and entrepreneurs. The engineers on the NASA Technology Application Team at Research Triangle Institute (RTI) provide an active interface among NASA, research institutions, and private businesses to assist in identifying and developing technology transfer opportunities. Technology Utilization Officers (TUs) are located at each of NASA's Field Centers and serve as the gateway for external inquiries to access the technological resources of their respective Centers. The following examples of technology spinoffs illustrate just a few of the benefits realized through secondary applications of aerospace technology.

Lixiscope

When scientists discovered that some galaxies and stars emit X-rays, they set about developing imaging techniques to enhance the relatively low levels of radiation coming from these far-off sources. Because the new detector developed was able to image low-intensity X-rays, this detector can be used with a much smaller X-ray source for less risky medical imaging procedures. This technology has taken the form of a low-intensity X-ray imaging scope (Lixiscope). Originally developed by Goddard Space Flight Center, the Lixiscope is being produced by Lixi, Inc. of Downers Grove, Illinois. The Lixiscope is a self-contained, battery-powered fluoroscope that produces an instant X-ray image through use of a small amount of radioactive isotope. This unit is designed to utilize less than 1 percent of the radiation required by conventional X-ray devices. Because this system is completely portable, it provides a way to immediately scan athletes for possible bone injuries at the site of the sporting event, or for other such emergency medical uses. Other applications for this system include dentistry and orthopedic surgery. The Lixiscope is finding growing acceptance as an industrial tool in the U.S. and abroad for rapid nondestructive testing for the development of X-ray film. It is also used in security applications, such as examining parcels in mail rooms and building entries.

Cardiac Defibrillation

Approximately 50,000 people die each year in the U.S. due to ventricular fibrillation, where the electrical conduction system of the heart becomes "short circuited." The muscles of the heart contract in a disorganized fashion, and the heart does not pump blood efficiently. When it can be applied in time, electric shock defibrillation is generally successful in restoring normal electrical activity to the heart. Unfortunately, most of those who die each year from a fibrillation episode are away from a hospital, where they could receive proper treatment.

As the population of astronauts became more diverse, the possibility of a cardiac episode needed to be considered. NASA's Johnson Space Center, in conjunction with International Biomedical of Houston, Texas, developed an advanced defibrillator monitoring system. This system combines the defibrillator paddles with a microprocessor-based monitoring system to display both treatment and patient information. The system is lightweight, portable, and easy to operate. Such equipment is being considered as part of a life support module for future shuttle flights.

In a related project, NASA's Goddard Space Flight Center, Johns Hopkins University, and Intec Systems, Inc., collaborated on the development of an implantable device capable of sensing ventricular fibrillation and delivering a brief defibrillating electrical pulse. The implant incorporates advanced microelectronics and sensors to provide programmability to adapt to individual patient requirements. Subsequently, the ability to detect and correct ventricular tachycardia, another form of arrhythmia, was added to the device. The resulting product, called the Automatic Implantable Cardioverter-Defibrillator (AICD) has been commercialized by Cardiac Pacemakers, Inc. Through telemetry, the device can be interrogated to determine if a defibrillating pulse has been provided, and if so, to look at the electrocardiogram just prior to and following the episode. Hundreds of life saving situations have been documented with use of this system.

Programmable, Implantable Medication System

Over one million Americans suffer from diabetes, a disease that destroys the body's ability to control its blood sugar and produces such serious complications as heart disease, kidney malfunction, and blindness. Yet most diabetics are able to live long, productive lives by closely monitoring blood sugar levels, continually injecting insulin, and carefully controlling diet and activity levels. Now, a new technology has emerged that may ultimately free diabetics and victims of other long-term diseases from their restrictive lifestyles. Engineers have developed a programmable, implantable medication system (PIMS) that will automatically deliver prescribed doses of medication to key areas in the body, eliminating the need for burdensome self-medication programs. In addition, research has shown that infusion of "short-acting" insulin in small

amounts over a long period - instead of multiple daily injections of "long-acting" insulin - has helped many diabetics achieve better control of blood sugar levels, thereby minimizing the possibility of complications. The device is the size of a hockey puck, is encased in a titanium shell, and holds about two-and-a-half teaspoons of concentrated insulin administered at a preprogrammed rate. If a change in measured blood sugar level dictates a different dose, the patient can vary the amount of insulin delivered by holding a small radio transceiver over the implanted system and dialing in a specific program held in the PIMS computer memory. A miniature two-way communications system, based on the space technology of telemetry, sends out signals from the implant with operating information such as insulin usage and pump performance. When an insulin refill is needed, four to six times a year, it is accomplished without surgery by a special hypodermic needle.

Johns Hopkins University's Applied Physics Laboratory (APL) headed the initial development of PIMS as a TU project sponsored by NASA's Goddard Space Flight Center. PIMS is an outstanding example of how space technology offers special utility in medical systems. PIMS employs several technologies derived from R&D work on NASA space systems, including a tiny, microminiaturized fluid control system initially used in life search experiments aboard two NASA Viking spacecraft that landed on Mars. MiniMed Technologies of Sylmar, California, licensee of the technology, has been refining the design of PIMS since the initial development at APL. The PIMS unit has performed well in clinical trials and is entering a second phase of trials for various applications. The technologies in PIMS have also been incorporated in portable external pumps marketed by MiniMed and by the Biomedical Group of Parker Hannifan Corporation, of Irvine, California. These pocket-sized micropumps allow ambulatory infusion of chemotherapeutic, antibiotic, and antipain medications.

On the Horizon

Two human imperatives, exploration and improving the condition of mankind, have found common ground in the space program. Technologies developed to meet the awesome challenges of space exploration in the past three decades have paid extra dividends in improving the quality of life on Earth. Medical innovations derived from space technology that may be seen in the next decade include: a technique for noninvasive measurement of intracranial pressure, a critical parameter in the treatment of head injury; a device for management of dangerous wandering behavior in Alzheimer's patients; improved heart valves made possible by computational fluid dynamics; an analytical technology developed for aerospace applications; and an adjustable shunt for improved control of cerebrospinal fluid pressure in children with hydrocephalus.